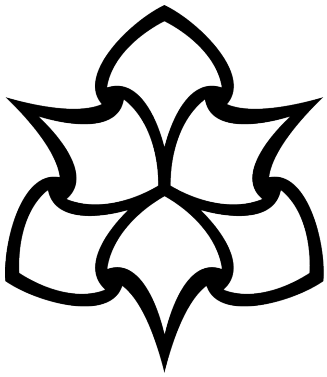

Transportation Research Part D 95 (2021) 102847

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

The case for a design-led, end-user focused airport noise management process

Graeme Heyes [a,*], Paul Hooper [a], Fiona Raje [a], Jack Sheppard [b]

[a] Manchester Metropolitan University, Ecology and Environment Research Centre, Department of Natural Sciences, Manchester Metropolitan University, Manchester M1 5GD, United Kingdom
[b] A Good Design Studio, 3 Fencegate Avenue, Stockport SK4 5EP, United Kingdom

ARTICLE INFO

Keywords:
Design thinking
Airport noise
Noise management
Innovation
Balanced approach
Human-centred design

ABSTRACT

Designing and implementing noise management actions is complex, with research showing that airports tend to develop such actions in an inconsistent manner, rather than through robust processes based on a rich evidence base, and that aim to deliver targeted outcomes, through evaluable interventions. This article presents some key airport noise management challenges, and proposes that a framework to guide noise managers in the development of management actions may enhance their capacity to respond to noise management challenges. The paper presents the concept of Design Thinking, a popular user-centric and iterative problem-solving approach. We argue that Design Thinking can play a key role in guiding noise managers through a series of propositions that lay the ground for future research to provide airports with the best possible guidance with which to develop – and implement – effective noise management actions.

1. Introduction

Environmental noise produced by airport activity is a major constraint to operations at many airports, and the source of well documented health impacts on local communities. Airport noise managers are thus required to respond to a variety of noise management problems over which they have influence, for example, the adoption of new interventions as described under the ICAO Balanced Approach, or their subsequent adaptation over time due to a range of factors including new technologies, changes to legislation, or changes to avoid overflying noise sensitive communities. Previous research in noise management at airports has focused on themes such as noise modelling and monitoring (El-Fadel et al., 2002; Torija, Self and Flindell, 2018), the use of metrics to describe the noise environment (Hooper and Flindell, 2013; Gasco, Asensio and de Arcas, 2017; Brink et al., 2018), policy (Murphy and King, 2010; King, Murphy and Rice, 2011), and the role of non-acoustic factors (Vader, 2007; Schreckenberg and Schuemer, 2010; Bartels, Márki and Müller, 2015) in the human response to noise. There has however been a paucity of research pertaining to the process that noise managers go through in order to understand which noise management actions may be effective in a given setting (i.e. the adoption of a Performance-Based Navigation optimised flight path), or how those actions should be implemented in real terms (i.e. where an optimised flight path should be located).

This paper discusses the range of noise management challenges that exist for airports in terms of the process of designing and implementing noise management interventions (Section 2). In so doing we highlight the need for guiding processes or frameworks that can assist in the development of noise management actions that can produce targeted and evaluable outcomes, and we highlight six key

* Corresponding author.
E-mail addresses: G.heyes@mmu.ac.uk (G. Heyes), jack@madebyshepperd.com (J. Sheppard).

https://doi.org/10.1016/j.trd.2021.102847

Available online 24 April 2021

requirements that should underpin any such process. In Section 3 we introduce the concept of Design Thinking (DT), a popular approach taken in the development of products and services, that has been used in strategic management contexts, and that is increasingly advocated in the academic literature for application to solve a range of environmental challenges. In Section 4, the potentially significant role that DT can have in guiding airport noise managers in the design and delivery of noise management actions is discussed via a series of research propositions, before the paper concludes in Section 5 with a call for research case study research to apply DT approaches in real noise management settings.

It is our belief that this paper makes an important contribution to the literature. It summarises the various challenges of implementing noise management interventions from a process perspective for the first time. Moreover, we believe that the paper represents the first time that DT has been introduced in a noise management context, thus representing an important transposition of methods from the strategic and management literature into noise management dialogues. Our propositions of the role that DT can play in guiding noise managers represents an important call to action for further investigation via case study research, and makes a significant contribution to the development of much-needed guidance material that can support noise managers in the design and delivery of noise management interventions.

2. The airport noise management challenge

The effective management of airport noise requires that noise managers address complex, varied and multi-scale challenges linked to noise induced health outcomes, including annoyance (Heyes et al., 2018b; Kranjec et al., 2019). This is accomplished through noise management strategies and actions that fall under four categories of the ICAO Balanced Approach (European Union, 2014), that may, for instance, seek to: reduce noise footprints or change the temporal or spatial distribution of noise (operational procedures); redistribute populations exposed to noise (land-use planning); and, protect people from noise (i.e. through insulation and noise zoning). More recently, researchers have identified a range of non-acoustic factors known to play a role in noise impact (Vader, 2007; Haubrich et al., 2019), and have stated that comprehensive approaches to noise management should aim to address such factors directly, through communication and engagement initiatives (Heyes et al., 2020), exemplified by public participation (Gasco, Asensio and de Arcas, 2017), that can provide for 'social-learning' (Webler, Kastenholz and Renn, 1995) to take place (Haubrich et al., 2019; Heyes et al., 2020), where through enhanced 'competence' and 'fairness' in the decision-making process, the public can unite to solve a problem.

The implementation of such management actions must be tailored to the specific and diverse needs of different airports, which can differ significantly depending on a range of characteristics (Heyes et al., 2018b). Indeed, such flexibility is at the core of the ICAO Balanced Approach (European Union, 2014), and the Environmental Noise Directive (European Union, 2002), which require airports of over 50,000 movements to produce strategic noise maps and develop noise action plans. A range of guidance exists to aid noise managers in developing noise management strategies and individual actions associated with the balanced approach (International Civil Aviation Organization, 2004). This includes guidance at the national level (Department for Transport, 2017), however for many nations such guidance is lacking (Heyes et al., 2018b). Moreover, the different characteristics of airports and the challenges that they face may mean that national guidance cannot be directly transposed between nations (Heyes et al., 2018b). Such guidance does not provide any sort of step-framework in terms of guiding an airport through the development of solutions to noise management challenges in a holistic manner (Heyes et al., 2019). Nor does it embed the emerging concepts of communication and engagement as means to influence non-acoustic factors in the development of noise management actions (Heyes et al., 2020). This is a particular challenge for small but rapidly growing airports that can quickly fall under legal requirements for noise management actions, but who may lack experience in their implementation. The danger is that they may seek 'copy-out' transpositions of what has been done elsewhere (i.e.

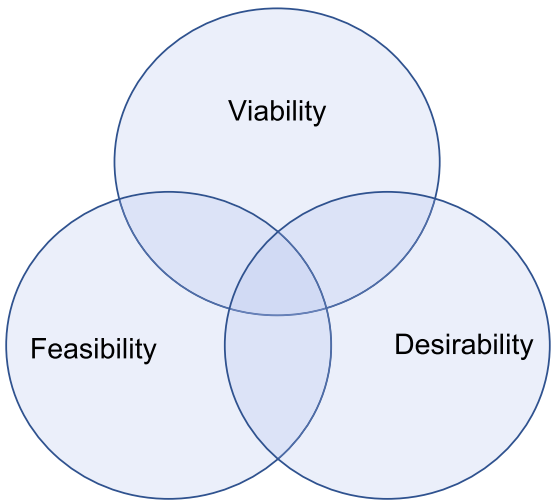

Fig. 1. Noise management action success factors (Adapted from Shapira, Ketchie and Nehe, 2017).

implementing what has been applied elsewhere rather than what may be most appropriate in their own setting). This approach is understandable and may be effective at demonstrating action in the short-term, however it may also lead to sub-optimal outcomes. This is particularly the case seeing how lead-edge airports are constantly developing and redefining their own noise strategies in response to the maturing noise management landscape, and an emerging research base. These findings are supported by research conducted in the H2020 ANIMA research project which highlighted that no universal best practice management actions that can be applied across airports due to the radically different characteristics of airports, their surrounding communities and the disparate range of management problems they may face as a result (Heyes et al., 2019).

Borrowing from the field of Human-Centred design (Shapira, Ketchie and Nehe, 2017), we illustrate the requirements of a successful noise management action below, and in Fig. 1, as needing to be:

- *Viable* in terms of complex factors such as safety, security, environmental interdependencies and legislative compliance;
- *Feasible* in terms of airport infrastructure and financial capabilities; and
- *Desirable* to industry and community stakeholders.

Each of these factors are heavily influenced by the characteristics of each airport, meaning that not only are universal best practice management actions difficult to propose, but airports need to understand which characteristics are important to their own circumstances, in order to increase the likelihood of interventions being successful. Such a process must also consider the complex multi-stakeholder nature of noise management and the fact that noise management actions ultimately exist to benefit the lives of residents. This implies that such a process should be:

- *Collaborative*, to enable cross-stakeholder input and consultation.
- *Iterative, yet flexible*, to help develop solutions to unique challenges in a robust manner than can be demonstrated to stakeholders.
- *Human-Centric and End-user focused*, to produce outcomes that seek to benefit residents in an empathetic way which takes due account of their perspectives and needs.
- *Impactful,* reflecting the need for management actions that can deliver targeted and evaluated outcomes that aim to address the core issues behind noise problems.

ANIMA research (Heyes et al., 2019) found that whilst airports tend to do a good job at understanding the viability and feasibility elements of developing noise management actions, responses to noise management problems were typically undertaken in an unstructured manner, lacking in targeted outcomes, and evaluation beyond quantitative measures such as reductions in noise level (as described through aggregated noise metrics such as Lden), and number of homes insulated or resources spent.

This is an important observation, as when taken together with the aforementioned importance of non-acoustic factors, the lack of 'desirability' focus in noise management can explain why the air transport industry has generally struggled in delivering reductions in noise impacts as described through complaints and annoyance. Both have risen in recent decades despite remarkable achievements by the aviation industry to reduce noise from source from individual aircraft. Indeed, aircraft today are some 75% quieter than they were 30 years ago (EC, 2021) and the fact that noise contours around airports have in many cases contracted. Complaints and reported annoyance at airports have, however, not shown a corresponding reduction, with annoyance rising in many areas owing to continued airport development and an increase in the awareness of aviation noise health impacts (Asensio, Gasco and de Arcas, 2017), indeed annoyance itself has been demonstrated to be a health impact in its own right (Kranjec et al., 2019; Haubrich et al., 2019). Part of this anomaly may be explained by the way in which airport noise is typically modelled, monitored, communicated, and used in decision making processes. Noise exposure is usually summarised utilising aggregated noise metrics (e.g. Leq) that, although useful at capturing the total exposure to sound energy over a given period and in helping define thresholds to inform decision making at the policy level, are less effective at explaining noise to residents, whose experience is dominated by the number, loudness and timing of events rather than by an artificial objective overview of overall exposure to sound energy. Thus, conventional level-equivalent based metrics have been criticised for being incomprehensible to non-experts and even exacerbating annoyance as they can mask acoustic attributes central to the perception of noise on the ground (Hooper and Flindell, 2013). This weakness is compounded by a failure of the industry to effectively evaluate and demonstrate outcomes of noise management interventions that are able to prove actual enhancements in resident perceptions of the noise source, the acceptability of management decisions, or changes in quality of life. From the aforementioned case analysis, Heyes et al. (2019) posit that by following the approach described below airports can better understand what effective practice looks like:

- the identification of a need to make a change;
- the design of a range of management actions;
- the selection of the most appropriate action; and,
- its implementation and subsequent on-going evaluation (Heyes et al., 2019).

Heyes et al. 2019 provide no additional information as to what such an approach may look like in real terms for airport managers and this suggests a place for a step-framework for noise management that can provide an iterative process of noise management action development and delivery. This approach is similar to the approach advocated in industry guidance such as the United Kingdom's Civil Aviation Authorities CAP 1616 document (CAA, 2021), and the United States FAA Part 150 Program (FAA, 2015). The former describes the modernisation of airspace in the United Kingdom and the Department for Transport's Air Navigation Guidance and its

consequent encapsulation in CAP 1616 (CAA, 2021). The latter specifies a 7 Stage design-agree-implement-evaluate process which acknowledges the need for stakeholder input into early stages of airspace design to build consensus on design principles. Stages are defined as: Define; Develop and assess; Consult; Update and submit; Decide; Implement; Post-implementation review. Although there is specific space for consultation in the first step here, identifying key stakeholders and incorporating their perspectives into the process is also called for in the preceding stages. The FAA Part 150 program provides a similar methodology and series of procedures that can be followed when preparing aircraft noise exposure maps and developing airport land use compatibility programs. The aim of Part 150 is to empower airports to think innovatively and creatively when addressing noise problems, and to do so in a manner that considers all stakeholders. In so doing, Part 150 can help to enhance the understanding of noise and the decisions made by airports in its management. In so doing, its application can lead to outcomes that are perceived to be fair and acceptable, based on an enhanced competence and understanding of noise.

Both the findings of ANIMA, CAA CAP1616 and FAA Part 150 suggest iterative processes can help airports in the development and implementation of noise management interventions. What is less clear however is how this level of engagement should be achieved and what it should include. Below we present 6 key requirements of what a standardised process to help inform on the development of noise management interventions and decision making might look like, and in the next section introduce the concept of design thinking, and its potential role in informing noise management processes more generally. The presented recommendations are based on the contextual information presented in the preceding sections of this paper, and on our experiences of working with aviation industry and stakeholder groups in the ANIMA project which set out to understand noise from an impact and management process perspective, rather than seeking to enhance noise management through purely technical innovations, such as via noise at source enhancements.

- Requirement 1: A process must be robust, yet flexible enough to lead to bespoke solutions to the unique challenges faced by different airports (Heyes et al., 2018b).
- Requirement 2: The process should embed concepts of stakeholder engagement and two-way dialogues to develop empathy, enhance opportunities for social-learning, and where appropriate, public participation in the decision-making process (Kranjec et al., 2019; Haubrich et al., 2019).
- Requirement 3: A process should consider stakeholder needs, including local citizens who are affected by, and who are the ultimately the primary beneficiaries of, noise management actions (Kranjec et al., 2019; Haubrich et al., 2019).
- Requirement 4: The process is able to support airport requirements to meet existing policy, for example the Environmental Noise Directive (European Union, 2002), and the ICAO Balanced Approach (European Union, 2014).
- Requirement 5: The process should generate noise actions based on targeted outcomes, valued by communities, that address core problems (for instance, involving qualitative non-acoustic factors), rather than focusing on quantitative data alone (for instance, through aggregated noise metrics such as Lden) (Heyes et al., 2019).
- Requirement 6: The process should be creative enough to consider novel solutions, whilst ensuring that any outcomes are consistent with a series of underpinning noise management principles that may be universal (i.e. safety and technological feasibility), or local (i.e. airport location, regional policy, airport priorities) in nature (Heyes et al., 2019).

3. Design thinking

3.1. The design thinking concept

Design Thinking (DT) is a human-centred (van der Bijl-Brouwer and Dorst, 2017) and iterative approach to problem-solving that

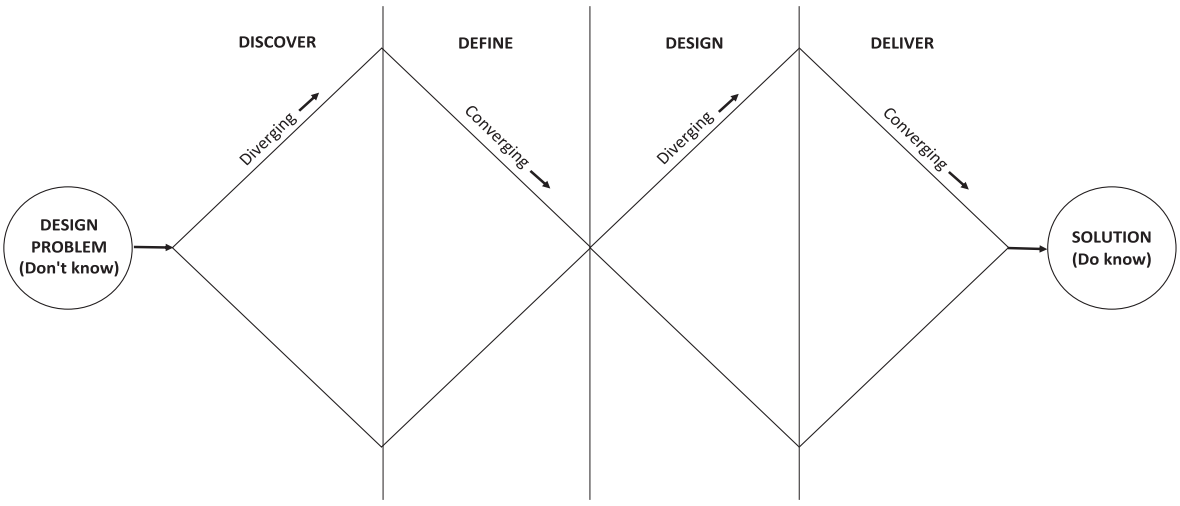

Fig. 2. The 'Double Diamond' design process. Adapted from Design Council (2020) and Nessler (2018).

emulates the ways in which designers think and work (Hoolohan and Browne, 2020). It is based on the idea that problems faced by organisations are complex, involve a range of stakeholders, and there may exist several layers of understanding required to comprehend and solve, the core design challenge. Through an iterative process, it is possible to move from a hypothetical starting question with an unknown answer, towards solutions that are empathetic to the needs of end-users and that are able to address the root cause of the problem at hand. There is no formal agreed upon definition of DT, and the concept has been critiqued for the fact that it was developed by innovation firm IDEO (IDEO, 2015) without proper academic grounding (Kimbell, 2011), however the concept has nonetheless become widely adopted by the design community, businesses and increasingly by researchers, who have been attracted to its ability to drive innovation and business success (Dorst, 2011; Johansson-Sköldberg, Woodilla and Çetinkaya, 2013; Glen et al., 2015; Redante et al., 2019). Redante et al. (2019) went as far as suggesting that DT can be used as an alternative approach to stakeholder engagement.

The DT process does not provide a hard and fast set of rules and actions. Rather, it is about creating a sequence of spaces in which different types of activities take place (Brown, 2008; Liedtka, 2015), notably need-seeking, brainstorming, and prototyping (Seidel and Fixson, 2013), or as Brown (2008) defines them: inspiration, ideation and implementation. The process also embeds concepts of collaboration (reflecting the fact that organisations and their challenges are complex and involve a range of stakeholders), iterative thinking (reflecting the fact that innovation requires phases of research, exploration and ideation), and end-user focus (accounting for the fact that products and services exist to serve the needs of those who use them, or are affected by them). A number of versions of the DT process exist, however all essentially follow the fundamental process outlined in the 'Double Diamond', described below and illustrated in Fig. 2.

The first two phases of the diamond (discovery and define) describe the aim of 'doing the right thing', by getting to the bottom of the problem and identifying what needs to change in order for the problem to be solved, and hence what kind of solutions might be appropriate. This is important as what may appear to be the problem at a superficial level may have its roots in a range of other factors that need to be addressed in order for the problem to be solved. The final two phases (design and delivery) describe the aim of 'doing things the right way' by exploring a range of suitable approaches to solve the problem faced, and through iterative exploratory processes identifying the best possible way to develop and deliver a solution to the original problem. The phases are typically described as diverging or converging. During a diverging phase, the design team aims to be as creative and open minded as possible, with the aim of maximising the potential to get to the bottom of the design challenge, or to identify its potential solution. In converging phases, the focus shifts to condensing and narrowing findings or ideas to provide focus, and ultimately, effective and implementable outcomes.

The process is typically led through a multi-stakeholder design team, which convenes to participate in, and drive the design process. An on-going design team can be beneficial in that it acts as an enduring group that aims to work together over time to address challenges as they arise. In so doing the team is able to develop long-term relationships amongst members and thus establish trust between each other, in the design process, and in their own creative capacity. The convening of the design team begins with what is termed the 'point of departure', which should include a review of the initial hypothesis, or design problem, to be addressed, followed by the establishment of DT principles that are necessary for the process to be successful. These include establishing roles and responsibilities, available resources and deadlines, the requirement for open two-way dialogues through which held expertise can be challenged, and the development of success and failure criteria. The key phases of DT are summarised in below, further descriptions of the process can be found in a wide range of sources in the academic and grey literature that advocate the approach to solve a range of organisational and societal problems (Seidel and Fixson, 2013; IDEO, 2015; Shapira, Ketchie and Nehe, 2017; Design Council, 2020; Hoolohan and Browne, 2020).

- Discover; The discovery phase sees the design team define the overarching problem as they currently understand it, and through the acquisition of primary or secondary research data look to provide additional insight into the question. Research often includes a strong qualitative element to reflect the empathetic, human-centeredness of DT. Every aspect of the initial problem is questioned to identify a range of elements, characteristics and areas of interest that can be explored. The findings from this activity can then be clustered into topics that provide an overview of the problem and areas that require investigation. With the key topics identified, research takes place to provide insight into the reality of the design problem.
- Define; Next the design team converge into a defining or interpretive stage, with the aim of assessing the collected information to form insights that may provide additional clarity or perspectives on the design problem. Creativity can be useful here to help bring the research to light, for example by synthesising data to 'tell stories' about the experiences of different stakeholders. Doing so is useful in building empathy for stakeholders. Following this session, the results are reviewed and clustered into themes of relevance as part of a 'search for meaning' so that insights can be drawn. The aim is to uncover the hidden truths that may (or may not) exist regarding the situation and can be particularly useful when considering human issues, such as people's frustrations, wishes, or perceptions regarding a specific topic. From this, opportunity areas can be identified that can be adapted into headline statements that can subsequently lead to the development of 'How Might We' questions designed to inspire the design process by acting as a tangible statement of what needs to be accomplished for the design problem to be addressed.
- Develop; With a better understood design problem uncovered and defined, it is now possible to begin to look at solutions in a workshop where the design team comes together to identify and evaluate solutions that aim to solve the redefined problem. The workshop can be broadly split into two sessions, the first being to brainstorm solutions related to the redefined design problem. It is important that this stage is approached with a creative and open mind with no judging or evaluation taking place as this can constrain thinking and the ability to think of potentially unique and powerful solutions. After the ideation phase, an evaluation phase takes place to appraise ideas and identify those with the most potential to solve the problem the group is attempting to solve. This is typically accomplished by placing the generated ideas on a matrix of impact and feasibility.

- Deliver; In the delivery phase, the design team converge once more to prototype, test, and refine the selected option, or options, in order to determine which is the most appropriate, and how it may be implemented. A key concept at this stage is the idea of 'minimal viable products'(MVPs) – simple representations of proposed solutions that can be tested as fast as possible by offering just enough for initial feedback to be obtained. These MVPs can then be developed and refined over time as they move closer and closer to becoming final products.

3.2. DT principles

In an application of DT to the concept of sustainable development, Buhl et al., (2019) cite the work of Carlgren et al. (2016), who, via a series of interviews with employees from a range of innovation and DT practitioners, distinguished five key principles that characterise DT. This classification has since been used by several authors to discuss DT in different settings (Glen et al., 2015; Carlgren et al., 2016a; Shapira, Ketchie and Nehe, 2017; Buhl et al., 2019; Dell'Era et al., 2020; Hoolohan and Browne, 2020; Nagaraj et al., 2020). These are:

- Problem framing; DT is built on the notion that "identifying a larger problem space helps create a larger solution space" (Carlgren et al., 2016b, p. 47). As such a key requirement of the process is not to begin with an assumption that the design problem is already understood, but rather having the confidence to acknowledge that there are a host of contextual factors that may not yet be understood, but which could lead to a better understanding of the problem, and thus the generation of solutions that might otherwise not have been arrived at. The iterative nature of DT means that the design problem can be redefined following data collection, in such a way that may inform on not just the outcome of the process, but also the criteria on which it was selected, and how it may be evaluated after implementation (Buhl et al., 2019).
- Empathy; humans, their needs, practices and preferences are placed at the centre of the design process (Shapira, Ketchie and Nehe, 2017). This sort of 'human-centred' approach acknowledges that humans are complex, with multiple experiences, pains, required gains, and priorities (Osterwalder and Pigneur, 2010; Liedtka, 2015; Carlgren et al., 2016b). Hence a cornerstone of DT is building empathy for stakeholders, through qualitative research, that can be refined over time through iterative learning.
- Diversity; Capturing inputs from a wide range of stakeholders and synthesizing them into the decision-making process through two-way dialogues is central to DT (Carlgren et al., 2016b). It refers to the incorporation of voices from different hierarchies, with different experiences who are able to provide a range of different perspectives on the design problem. The DT process can act as a means to level such hierarchies ensuring that all voices are heard, and thus increasing the likelihood for novel outcomes, rather than outcomes based on the understanding of a limited number of people used to working in a certain way (Buhl et al., 2019).
- Visualisation; Visualising helps to make abstract ideas tangible. For instance, prototypes can be made more real by telling stories, through the use of simple prototype 'mock-ups'(Carlgren et al., 2016b; Buhl et al., 2019). As well as helping to gather empathy for end-users, such visualisation can help to gather feedback and thus aid further experimentation and development of ideas (Liedtka, 2015).
- Experimentation and iteration; the iterative nature of DT enables assumptions to be tested and refined, for trials and prototyping to take place, and for ideas and concepts to evolve over time as the evidence base for the potential success (or failure) builds through iterative testing and evaluation (i.e. through modelling, monitoring and user feedback). This sort of experimental thinking can provide greater freedom for creativity by ensuring that ideas can be evaluated and refined, rather than teams sticking at the first solution that they arrive at (Shapira, Ketchie and Nehe, 2017).

4. Design thinking for noise management

As outlined in Section 2, airport noise managers face a number of challenges in terms of the process that underpins the successful design and implementation of management actions. As stated in the ANIMA project, airports can benefit from a step-framework to help work through such processes, but at present no such frameworks exist, beyond a generic outline provided by ANIMA researchers (Heyes et al., 2019). Whilst there is no evidence of DT being applied in a noise management context, design and DT have been used to solve a range of environmental challenges (Tukker and Tischner, 2006; Braungart, McDonough and Bollinger, 2007; Carlsson et al., 2015; Geissdoerfer, Bocken and Hultink, 2016; Fischer and Pascucci, 2017; Prendeville and Bocken, 2017; Shapira, Ketchie and Nehe, 2017; Maher et al., 2018; Buhl et al., 2019; Rocha, Antunes and Partidário, 2019; Hoolohan and Browne, 2020). Similar iterative processes that take an initial research problem and creatively generate solutions and pathways to implementation have also been used extensively in the management, strategy and innovation fields (Boardman, Shapiro and Vining, 2004; Heyes, 2016; Broman and Robèrt, 2017; Mendoza et al., 2017; Heyes et al., 2018a). Perhaps most notably, DT principles have also previously been used to solve a range of aviation industry challenges related to issues such as safety, air cabin design, and digital services, by organisations such as airlines, the military, and NASA (Hall et al., 2013; Goodheart, 2016; ThisIsDesignThinking.net, 2016; McGowan et al., 2017; Turner Donald, 2017; Design For Europe, 2020).

Considering the noise management challenges and requirements outlined at the start of this article, and the characteristics of DT introduced above, the case for adopting design processes to guide noise managers in solving noise problems is compelling. Taking a similar approach to that used by Buhl et al., (Buhl et al., 2019), who proposed DT as a suitable tool for sustainability-orientated innovation, we summarise the requirements for a noise action development process below, and describe how we see DT as playing

an informing role as a series of propositions that we hope can be further investigated through future research, and invite others to further this work through research or dialogue.

- **Requirement 1:** A process must be robust, yet flexible enough to lead to bespoke solutions to the unique challenges faced by different airports.

Proposition. *The iterative nature of DT means that it is able to build a deep understanding of a noise management problem, creatively ideate solutions to that problem, and enable the one deemed most likely to succeed being selected through relevant success criteria. Moreover, the Delivery phase of DT is driven around the idea of prototyping and evaluation, which fits well with airport tools such as noise monitoring and modelling, scenario development and forecasting, as well as trials, and consultation events – all of which can lead to interventions being refined over time.*

- **Requirement 2:** The process should embed concepts of stakeholder engagement and two-way dialogues to develop empathy, enhance opportunities for social-learning, and where appropriate, public participation in the decision-making process.

Proposition. *DT fits perfectly with these ideals in that the process is inherently multi-stakeholder, with all stakeholders recommended to be represented in the design team, or as a minimum having their needs and perspectives accounted for in the Discovery phase. Likewise, empathy building and human-centric ideation enhances the potential for outcomes to be developed with stakeholder needs as a key concern. It does this by building stories of experiences rather than explaining things purely through quantitative data.*

- **Requirement 3**: A process should consider stakeholder needs, including local citizens who are affected by, and who are the ultimately the primary beneficiaries of noise management actions.

Proposition. *Similar to requirement 2, DT is inherently 'end-user' focused, and so able to consider the needs of all airport stakeholders, including the communities who are the ultimate beneficiaries of noise management actions. Evaluation criteria developed by the airport can raise or lower the importance of community needs as deemed appropriate by the design team, and based on wider airport strategy. In this way stakeholder values can be fully explored and help in determining the desirability of proposed courses or action.*

- **Requirement 4:** The process is able to support airport requirements to meet existing policy, notably the Environmental Noise Directive (European Union, 2002), and the ICAO Balanced Approach (European Union, 2014).

Proposition. *DT is perfectly suited to ensuring that wider policy and other requirements (i.e. from industry, or as articulated by senior airport management) are accounted for, and in such a way that policy priorities can be put into the context of stakeholder expectations. The process is capable of considering any outcomes (including those articulated through the Balanced Approach), whilst the evaluation of ideated solutions can ensure that selected outcomes of the process are consistent with airport noise action plans. Indeed, the DT process may itself be used to help develop noise action plans.*

- **Requirement 5:** The process should generate noise actions based on targeted outcomes that address core problems (that may involve qualitative non-acoustic factors), rather than those based on quantitative data alone (i.e. through aggregated noise metrics such as Lden).

Proposition. *The iterative nature of DT, including iterative learning in the discovery phase, can empower the design team to capture any information that is perceived to be of relevance to the noise management problem, thus enabling the core characteristics of the problem to be understood. Furthermore, DT is well suited to considering non-acoustic factors and other qualitative data, through the application of workshops, focus groups and interviews, and articulating such factors through creative methodologies such as story-telling.*

- **Requirement 6**: The process should be creative enough to consider novel solutions, whilst ensuring that any outcomes are consistent with a series of underpinning noise management principles that may be universal (i.e. safety and technological feasibility), or local (i.e. airport location, regional policy, airport priorities) in nature.

Proposition. *The design phase of DT begins with 'green-light' brainstorming, aimed to facilitate novel ideas to the management problem. However, a secondary phase of brainstorm analysis is able to identify which of the ideated options are feasible, and to evaluate them against*

selection-criteria developed by the design team based on the desirability of the outcomes discussed. These processes are often visually sketched or told through stories to better visualise proposed innovations and to help foster empathy. The design phase, and DT in general, also takes an iterative process of ideation, testing, and revision so that outcomes can move from initial concepts to tested, evaluated and implemented solutions.

Overall, this step-process provides a structure to achieve a comprehensive understanding of all the dimensions of a noise problem and to inform those attributes of a potential solution that provide for the most desirable outcomes, thereby ensuring that potential courses of action are impactful and that evaluation is fully aligned to the desirability criteria established through application of the design thinking process.

As an exploratory article, we recognise that there is much we do not know about the potential for DT to inform noise management actions, even though we believe the case is compelling. Specifically, we acknowledge a number of barriers to DT methods being adopted by noise managers, which are explored below:

- The process needs time and commitment, as well as the acquisition of new skills to either lead the DT process, or to work through the process with a practitioner in a creative, collaborative and open manner.
- Creative thinking may be challenging for some individuals, as it requires confidence in one's own abilities, and may go against organisational or institutional practice.
- The collaborative nature of DT means potentially giving away control to other stakeholders, which can be a daunting proposition for any organisation – although the establishment of noise management principles is part of the process, and hence influences the perceived feasibility and impact of developed solutions in the design phase, which should ensure that proposed solutions are viable and lead to desirable outcomes.
- DT is best performed with expert facilitation by DT professionals. Airports should either seek independent facilitation (in so doing also helping to overcome issues with trust by providing an independent voice), or follow as yet undeveloped guidance for DT facilitation similar to those produced for other sectors (IDEO, 2015).
- Noise stakeholders can differ significantly, and gaining equal and fair representation from all parties may be challenging.
- In some cases, there may not be a perfect solution to a noise problem and obtaining a consensus agreement between the design team may be difficult and require some participants to cede on certain issues. This can be a particular challenge when the development of a noise solution may result in 'winners' and 'losers' from, for instance, deciding where a flight path may be best situated in densely populated areas.
- Integrating community members in to a design team may be challenging in terms of recruitment and facilitation. Those likely to volunteer to a DT process are likely to be from the 'vocal minority' of community voices who complain and campaign about noise. Such individuals are typically more distrustful of airport activity and obtaining their buy-in to the design process could be difficult, and participation could prove to be non-constructive.
- Much of DT can take place in a small number of workshops, however the research and delivery phases can be time intensive, meaning that a full DT process may not be suitable when a rapid response is required.

Despite these barriers, we believe that the track record of DT at solving complex issues, and the synergies between the design process and the requirements for a noise management framework, mean that there is potential for design processes to inform on the development of a flexible yet structured and iterative approach to thinking about, and solving noise challenges. We call for the research community to contribute to understanding and overcoming these barriers through case study research with airports. Such research should seek to gain expert input into the potential development of a tailored design-led noise management process that can be tested in a real setting and to identify what barriers exist, and how they can be overcome. Doing so should assess how the phases of DT described in this article may need to be adapted, or if alternative models may be more suitable.

5. Conclusion

Airport noise management is a complex subject, with influencing factors at both the macro- (complying with international and national policy), and the micro-level (implementing noise management actions designed to benefit individual communities). As such, noise managers are faced with the difficult challenge of satisfying a range of stakeholders with different priorities and different levels of comprehension regarding the noise challenge, and a range of complex technical and legislative factors. For large airports, the challenge can be acute, due to the potentially significant number of people exposed to noise, due to encroachment around the airport, and the sheer number of aircraft movements making absolute reductions in noise level difficult, and with many interventions that benefit some, having the potential to disbenefit others. For smaller airports, the noise challenge may not be as urgent, however such airports often lack the experience of larger airports, and may not have the same resources available. The result can be that opportunities such as preventing the encroachment of noise sensitive dwellings, which could have benefit into the long term, are not fulfilled, as 'copy-out' transpositions of what has been attempted at larger airports may be sought after instead.

Recent research has highlighted that airports appear to lack a systematic approach to noise management based on iterative steps of thinking, and that this could lead to sub-optimal outcomes from interventions, notably through noise problems being poorly defined, and stakeholder perspectives being inadequately considered in the development process. In this article we presented Design Thinking as having the potential to inform on the development of a process that could guide airports in the development of noise actions, owing to its capacity to: (i) frame problems clearly, revealing the core challenges that underpin them – including non-acoustic factors, (ii)

include the perspectives of a wide range of stakeholders and (iii), develop empathy for them – ensuring that actions are more likely to be accepted, or that the attitude towards them is likely to be enhanced, (iv) creatively ideate novel solutions and demonstrate them through visualisation, and (v), enable such solutions to be investigated and developed iteratively based on quantitative and qualitative data, including trialling, modelling, and the use of trials.

Hence, we believe that DT represents a method to overcome airport noise challenges, if not in terms of formal adoption of the DT process, then as a guiding framework of principles, and the requirement for a sequence of spaces in which different types of activities take place. Research has demonstrated that no universal best practice solutions to noise management exist, but that effective practice is defined by the system through which airports design noise management strategies that are suitable for their own circumstances, and the characteristics of the challenges they face. In this sense we believe that DT can make a valuable contribution that may drastically enhance the capacity of managers to develop effective interventions.

We are exploring opportunities to further explore research in this area and call for other researchers interested in enhancing airport noise management to consider how DT can be implemented by themselves or by airports, in such a way that its advantages can be exploited, and barriers to implementation can be circumvented. Such discussion may also include an assessment of the proposed requirements of such a process framework, including the addition of any other requirements that may further inform on the role of DT in noise management contexts. We also call for noise managers to begin to think more like designers, by approaching noise management problems with creativity, collaboration, and human-centred empathy to their stakeholders.

Funding

This work reflects the perspectives of the researchers based on their expertise in noise management, and their experience in working in environmental management, strategy, and innovation fields. The authors acknowledge the contribution of EU project ANIMA (Grant agreement ID: 769627) to the initiation of some the ideas presented here; but their development has been conducted independently. The authors are solely responsible for the content presented, and the opinions expressed.

CRediT authorship contribution statement

Graeme Heyes: Conceptualization, Writing - original draft. **Paul Hooper:** Writing - review & editing, Supervision. **Fiona Raje:** Writing - review & editing, Supervision. **Jack Sheppard:** Conceptualization, Writing - original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Bartels, S., Márki, F., Müller, U., 2015. The influence of acoustical and non-acoustical factors on short-term annoyance due to aircraft noise in the field - The COSMA study. Sci. Total Environ. 538, 834–843. https://doi.org/10.1016/j.scitotenv.2015.08.064.

van der Bijl-Brouwer, M., Dorst, K., 2017. Advancing the strategic impact of human-centred design. Des. Stud. 53, 1–23. https://doi.org/10.1016/j.destud.2017.06.003.

Boardman, A., Shapiro, D., Vining, A., 2004. A framework for comprehensive strategic analysis. J. Strategic Manage. Educ.

Braungart, M., McDonough, W., Bollinger, A., 2007. Cradle-to-cradle design: creating healthy emissions - a strategy for eco-effective product and system design. J. Cleaner Prod. 15 (13–14), 1337–1348. https://doi.org/10.1016/j.jclepro.2006.08.003.

Brink, M., et al., 2018. Conversion between noise exposure indicators Leq24h, LDay, LEvening, LNight, Ldn and Lden: principles and practical guidance. Int. J. Hyg. Environ. Health 221 (1), 54–63. https://doi.org/10.1016/j.ijheh.2017.10.003.

Broman, G.I., Robèrt, K.H., 2017. A framework for strategic sustainable development. J. Cleaner Prod. 140, 17–31. https://doi.org/10.1016/j.jclepro.2015.10.121.

Brown, T., 2008. Design thinking. Harvard Bus. Rev. https://doi.org/10.5749/minnesota/9780816698875.003.0002.

Buhl, A., et al., 2019. Design thinking for sustainability: Why and how design thinking can foster sustainability-oriented innovation development. J. Cleaner Prod. 231, 1248–1257. https://doi.org/10.1016/j.jclepro.2019.05.259.

CAA, 2021 Airspace Change. Guidance on the regulatory process for changing the notified airspace design and planned and permanent redistribution of air traffic, and on providing airspace information. CAP 1616. Civil Aviation Authority. March 2021. Available on-line: Guidance on the regulatory process for changing the notified airspace design and planned and permanent redistribution of air traffic, and on providing airspace information. CAP 1616. Available at: https://publicapps.caa.co.uk/docs/33/CAA_Airspace%20Change%20Doc_Mar2021.pdf (Accessed: 09 March 2021).

Carlgren, L., Elmqvist, M., Rauth, I., 2016a. Exploring the use of design thinking in large organizations: towards a research agenda. Swedish Design Res. J. 11 (1), 55. https://doi.org/10.3384/svid.2000-964x.14155.

Carlgren, L., Rauth, I., Elmquist, M., 2016b. Framing design thinking: the concept in idea and enactment. Creativity Innov. Manage. https://doi.org/10.1111/caim.12153.

Carlsson, A., et al., 2015. Sustainability Jam Sessions for vision creation and problem solving. J. Cleaner Prod. https://doi.org/10.1016/j.jclepro.2014.10.041.

Dell'Era, C., et al., 2020. Four kinds of design thinking: from ideating to making, engaging, and criticizing. Creativity Innov. Manage. 29, 324–344. https://doi.org/10.1111/caim.12353.

Department for Transport, 2017. UK Airspace Policy: A framework for balanced decisions: on the design and use of airspace: Moving Britain Ahead. Available at: www.gov.uk/government/publications (Accessed: 9 June 2020).

Design Council, 2020. The Double Diamond: 15 years on | Design Council. Available at: https://www.designcouncil.org.uk/news-opinion/double-diamond-15-years (Accessed: 23 June 2020).

Design For Europe, 2020. Brussels Airlines | Design for Europe. Available at: http://www.designforeurope.eu/case-study/brussels-airlines (Accessed: 11 June 2020).

Dorst, K., 2011. The core of "design thinking" and its application. Des. Stud. 32 (6), 521–532. https://doi.org/10.1016/j.destud.2011.07.006.

El-Fadel, M., et al., 2002. Assessment of noise impacts at airports. Int. J. Environ. Stud. 59 (4), 447–467. https://doi.org/10.1080/00207230212739.

EC, 2021. Aircraft Noise. The European Commission. Available at: https://ec.europa.eu/transport/modes/air/environment/aircraft_noise_en (Accessed:08 March 2021).
European Union, 2002. DIRECTIVE 2002/49/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 June 2002 relating to the assessment and management of environmental noise.
European Union, 2014. Regulation (EU) No 598/2014 of the European Parliament and of the Council of 16 April 2014 on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Union airports within a Balanced Approach and repealing Directive 2002/30/EC.
FAA, 2015. Fact Sheet – The FAA Airport Noise Program. Federal Aviation Authority. Available at: https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=18114#:~:text=Airports%20may%20collaboratively%20address%20noise,The%20program%20began%20in%201981 (Accessed:08 March 2021).
Fischer, A., Pascucci, S., 2017. Institutional incentives in circular economy transition: the case of material use in the Dutch textile industry. J. Cleaner Prod. 155, 17–32. https://doi.org/10.1016/j.jclepro.2016.12.038.
Gasco, L., Asensio, C., de Arcas, G., 2017. Communicating airport noise emission data to the general public. Sci. Total Environ. https://doi.org/10.1016/j.scitotenv.2017.02.063.
Asensio, C., Gasco, L., de Arcas, G., 2017. A review of non-acoustic measures to handle community response to noise around airports. Curr. Pollut. Rep. 3, 230–244. https://doi.org/10.1007/s40726-017-0060-x.
Geissdoerfer, M., Bocken, N.M.P., Hultink, E.J., 2016. Design thinking to enhance the sustainable business modelling process – A workshop based on a value mapping process. J. Cleaner Prod. 135, 1218–1232. https://doi.org/10.1016/j.jclepro.2016.07.020.
Glen, R., et al., 2015. Teaching design thinking in business schools. Int. J. Manage. Educ. 13 (2), 182–192. https://doi.org/10.1016/j.ijme.2015.05.001.
Goodheart, B., 2016. Design Thinking for aviation safety. Aviation Bus. J. 4.
Hall, A., et al., 2013. Future aircraft cabins and design thinking: optimisation vs. win-win scenarios. Propul. Power Res. 2 (2), 85–95. https://doi.org/10.1016/j.jppr.2013.04.001.
Haubrich, J., et al., 2019. ANIMA D2.4 - Recommendations on annoyance mitigation and implications for communication and engagement. doi: 10.5281/ZENODO.2616668.
Heyes, G., 2016. The Potential for Sustainable Business Model Innovation: A Case Study of the Airport Retail Sector. Manchester Metropolitan University.
Heyes, G., et al., 2018a. Developing and implementing circular economy business models in service-oriented technology companies. J. Cleaner Prod. 177, 621–632. https://doi.org/10.1016/j.jclepro.2017.12.168.
Heyes, G., et al., 2019. ANIMA D2.5 - Critical review of Balanced Approach Implementation across EU Member States. doi: 10.5281/ZENODO.3146128.
Heyes, G., et al., 2020. Exemplar Case Studies of Aviation Noise Mitigation Strategies in the European Union: A Review of the communication and engagement state of the art.
Heyes, G., Dimitriu, D., Hooper, P., 2018. ANIMA D2.1 - Pan-European overview of Existing Knowledge and Implementation of Noise Reduction Strategies. doi: 10.5281/ZENODO.2599726.
Hoolohan, C., Browne, A.L., 2020. Design thinking for practice-based intervention: co-producing the change points toolkit to unlock (un)sustainable practices. Des. Stud. 67, 102–132. https://doi.org/10.1016/j.destud.2019.12.002.
Hooper, P., Flindell, I., 2013. Exchanging aircraft noise information with local communities around airports: The devil is in the detail. In: 42nd International Congress and Exposition on Noise Control Engineering 2013, INTER-NOISE 2013: Noise Control for Quality of Life.
IDEO, 2015. Design Kit: The Human-Centered Design Toolkit | ideo.com. Available at: https://www.ideo.com/post/design-kit (Accessed: 11 June 2020).
International Civil Aviation Organization, 2004. Guidance on the Balanced Approach to Aircraft Noise Management (Doc 9829).
Johansson-Sköldberg, U., Woodilla, J., Çetinkaya, M., 2013. Design thinking: past, present and possible futures. Creativity Innov. Manage. 22 (2), 121–146. https://doi.org/10.1111/caim.12023.
Kimbell, L., 2011. Rethinking design thinking: Part I. Des. Cult. 3 (3), 285–306. https://doi.org/10.2752/175470811x13071166525216.
King, E.A., Murphy, E., Rice, H.J., 2011. Implementation of the EU environmental noise directive: lessons from the first phase of strategic noise mapping and action planning in Ireland. J. Environ. Manage. 92 (3), 756–764. https://doi.org/10.1016/j.jenvman.2010.10.034.
Kranjec, N., et al., 2019. ANIMA D2.3 - Recommendations on noise and health. doi: 10.5281/ZENODO.2562749.
Liedtka, J., 2015. Perspective: linking design thinking with innovation outcomes through cognitive bias reduction. J. Prod. Innov. Manage. Blackwell Publishing Ltd 925–938. https://doi.org/10.1111/jpim.12163.
Maher, R., et al., 2018. Integrating design thinking with sustainability science: a Research through Design approach. Sustain. Sci. 13 (6), 1565–1587. https://doi.org/10.1007/s11625-018-0618-6.
McGowan, A.M., Bakula, C., Castner, R., 2017. Lessons learned from applying design thinking in a nasa rapid design study in aeronautics. In: 58th AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, 2017.
Mendoza, J.M.F., et al., 2017. Integrating backcasting and eco-design for the circular economy: the BECE Framework. J. Ind. Ecol. 21 (3), 526–544. https://doi.org/10.1111/jiec.12590.
Murphy, E., King, E.A., 2010. Strategic environmental noise mapping: methodological issues concerning policy implications. Environ. Int. 36 (3), 290–298. https://doi.org/10.1016/j.envint.2009.11.006.
Nagaraj, V., et al., 2020. Team design thinking, product innovativeness, and the moderating role of problem unfamiliarity. J. Prod. Innov. Manage 37 (4), 297–323. https://doi.org/10.1111/jpim.12528.
Nessler, D., 2018. How to apply a design thinking, HCD, UX or any creative process from scratch, Medium. Available at: https://medium.com/digital-experience-design/how-to-apply-a-design-thinking-hcd-ux-or-any-creative-process-from-scratch-b8786efbf812 (Accessed: 23 June 2020).
Osterwalder, A., Pigneur, Y., 2010. Business Model Generation – Canvas. Wiley.
Prendeville, S., Bocken, N., 2017. Sustainable business models through service design. Procedia Manuf. 8, 292–299. https://doi.org/10.1016/j.promfg.2017.02.037.
Redante, R.C., et al., 2019. Creative approaches and green product development: using design thinking to promote stakeholders' engagement. Sustainable Prod. Consum. 19, 247–256. https://doi.org/10.1016/j.spc.2019.04.006.
Rocha, C.S., Antunes, P., Partidário, P., 2019. Design for sustainability models: a multiperspective review. J. Cleaner Prod.. Elsevier Ltd 1428–1445. https://doi.org/10.1016/j.jclepro.2019.06.108.
Schreckenberg, D., Schuemer, R., 2010. The impact of acoustical, operational and non-auditory factors on short-term annoyance due to aircraft noise. In: 39th International Congress on Noise Control Engineering 2010, INTER-NOISE 2010.
Seidel, V.P., Fixson, S.K., 2013. Adopting design thinking in novice multidisciplinary teams: the application and limits of design methods and reflexive practices. J. Prod. Innov. Manage 30 (SUPPL 1), 19–33. https://doi.org/10.1111/jpim.12061.
Shapira, H., Ketchie, A., Nehe, M., 2017. The integration of design thinking and strategic sustainable development. J. Cleaner Prod. 140, 277–287. https://doi.org/10.1016/j.jclepro.2015.10.092.
ThisIsDesignThinking.net, 2016. Be rebellious! How ANA is Utilizing Design Thinking to Connect its Past with its Future | This is Design Thinking! Available at: https://thisisdesignthinking.net/2016/12/ana-design-thinking-japan/ (Accessed: 11 June 2020).
Torija, A.J., Self, R.H., Flindell, I.H., 2018. Airport noise modelling for strategic environmental impact assessment of aviation. Appl. Acoust. 132, 49–57. https://doi.org/10.1016/j.apacoust.2017.10.017.
Tukker, A., Tischner, U., 2006. Product-services as a research field: past, present and future. reflections from a decade of research. J. Cleaner Prod. 14 (17), 1552–1556. https://doi.org/10.1016/j.jclepro.2006.01.022.
Turner Donald, E.I.I.I., 2017. A case study in Design Thinking applied through Aviation Mission Support Tactical Advancements for the Next Generation (TANG). Calhoun. Available at: https://calhoun.nps.edu/handle/10945/56830.
Vader, R., 2007. D/R&D 07/026 Noise Annoyance Mitigation at Airports by Non-Acoustic Measures.
Webler, T., Kastenholz, H., Renn, O., 1995. Public participation in impact assessment: a social learning perspective. Environ. Impact Assess. Rev. 15 (5), 443–463. https://doi.org/10.1016/0195-9255(95)00043-E.